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TITLE: Successive and faster statistical reconstruction applied to streak artifact reduction in X-ray computed tomography image of dento-alveolar region

Authors: Yoshihiko Hayakawa, Jian Dong, Kosuke Abe and Atsushi Kondo
Affiliations: Dept. of Computer Science, Kitami Institute of Technology
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Purpose: X-ray computed tomography (CT) images in the dento-alveolar region are sometimes rendered unusable for diagnostic purposes due to the appearance of streak artifacts. They are mainly caused by the existence of metallic prosthetic appliances which have high atomic numbers and high density, but are also caused by, e.g., dental fillings in the oral cavity [1]. The metallic prosthetic appliances partly cause the lack of the projection data during the CT examination. Therefore, the resulting CT sinogram is often corrupted by the missing data. And as a result, the filtered back projection (FBP) algorithm, the traditional CT reconstruction method used for cross-sectional image reconstruction, cannot deal with such metal-induced inconsistencies, and the sinogram is rendered useless. However, several algorithms have been proposed for the reduction of metal-induced streak artifacts. In some reports, the corrupted portions of the sinogram are replaced by uncorrupted data using appropriate interpolation methods[2]. In contrast, statistical reconstruction methods have been applied for image reconstruction in emission CT. For example, this type of application has been reported for the reduction of streak artifacts. Moreover, the huge amount of computational efforts which this method requires has been resolved by the advancement in computer hardware. These are reconstruction methods that use an iterative restoration algorithm.

However, our approach is quite different from those described in previous reports [3,4]. Due to advancements in hardware and software in CT systems and clinical needs, the CT examination with thin slice thickness is carried out in the dento-alveolar region as well as head and trunk regions. We found that an artifact-free/intact slice depicted very similar anatomical structures to the adjacent slice that contained the heavy streak artifacts, and therefore they were the target of the proposed processing [3]. Therefore, we applied the maximum likelihood-expectation maximization (ML-EM) reconstruction algorithm to MDCT images. After all, the processing was practically an iterative correction. A slice having heavy streak artifact was processed using the projection data of an intact slice [3]. But there are several slices (seven slices in each 0.5 mm thickness) between them, and some streak artifacts were observed on the seven images. As the result, some deviations between the original image and the processed image were indicated. In the second report [4], the successive iterative restoration to an image with streak artifacts using the immediate neighboring artifact-free slice was carried out and such successive processing achieved the artifact reduction while minimizing anatomical structure deviations.

The purpose of the study is to reduce streak artifacts appeared on dental and maxillofacial X-ray CT images by the application of modified iterative restoration method and the faster algorithm.

Methods: The MDCT examination of the maxillary sinus and maxilla was carried out using a Somatom Plus 4 Volume Zoom (Siemens, Erlangen, Germany). Principal exposure parameters were as follows: 120 kV, 130 effective mAs, and a slice thickness of 0.5 mm. The pixel matrix of each slice was 512 × 512. Severe metal-induced streak artifacts occurred at several tooth crowns in the maxilla, and in addition, the overlapped regions were invisible.

We took advantage of the aspect that adjacent CT images often depict very similar anatomical structures within the resulting collection of thin-slice images. CT images having streak artifacts was processed using the projection data of adjacent CT images. A modified iterative correction, the maximum likelihood-expectation maximization (ML-EM) reconstruction algorithm, was employed to reduce the streak artifact caused by metallic materials in the oral cavity. It approximates between the processed image and the original projection data. First the projection data of an intact image was obtained and then the next image which had streak artifacts was processed. The projection data of the processed image were obtained and the ML-EM method was applied to the next image again. Then the successive iterative restoration was carried out.

We applied the ordered subset-expectation maximization (OS-EM) reconstruction algorithm for the processing. The original projection data were divided into a couple of subsets. The number of subsets was changed from 1, 4, 6 and 8. Each subset contains 24, 6, 4 and 3 projection data.

Results: Twelve adjacent images were processed. Each iterative restoration was carried out fifty times. Processed images at the initial stage were blurred, but clearly some streak artifacts were disappeared according to the repeated approximation. Streak artifacts were observed on processed images at the initial stage, but some of them either suppressed or disappeared as the iteration progressed.

The OS-EM method was possible to work for reducing the calculation loading. When the number of subset was 8 and 3 projection data was contained in each, the number of iterative restoration was enough to be five times and the time for the calculation was only 5 min. The degradation of the image quality was observed according to the increase of the number of subsets and iterative restoration.

Conclusion: The modified ML-EM method was effective to reduce streak artifacts in X-ray CT images in dento-alveolar region. The OS-EM method worked for the fast calculation.

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